Original Article

A STUDY ON SMART BUILDING PRACTICE ADOPTION BY ARCHITECTURE, ENGINEERING, AND CONSTRUCTION EXPERTS IN ABUJA

Udoh Iniobong Emmanuel, Akpan Uduak Christophe and Uchechukwu Onoriode James

Department of Technical Education, Akwa Ibom State College of Education, Afaha Nsit, Nigeria

Department of Civil Engineering, Delta State University of Science and Technology, Ozoro, Delta State, Nigeria
DOI:https://doi.org/10.5281/zenodo.15461980

Abstract: This paper evaluated Architecture, Engineering and Construction (AEC) professionals' adoption of Smart Building practices (SBP) in Federal Capital Territory (FCT), Abuja, Nigeria. Three research questions and descriptive survey design were used for the study. The population of 628 Construction professionals consisted of 98 Architects, 117 Civil Engineers and 103 Electrical Engineers duly registered with the Architects Registration Council of Nigeria (ARCON) and Nigerian Society of Engineers (NSE). Purposive sampling technique was used to select 154 Construction professionals consisted of 49 Architects, 54 Civil Engineers and 51 Electrical Engineers. The sample size selection was made using the Yamane formula for calculating sample size. A 30-item questionnaire based on a 5-point rating scale for data collection. Face validation of the instrument was carried out by three professionals who were not part of the study, while the reliability of the instrument was ascertained using Cronbach Alpha statistics which yielded overall reliability index of .80 comprising of .81, .83 and 77 for Section B, C and D respectively indicating that the instrument was reliable. The research questions were analyzed using Mean and standard deviation. The findings of the study indicated that AEC professionals lowly adopt Smart Building Practices in the study area. The study findings also showed that high cost of smart building materials, inadequate power supply, poor knowledge of smart building technology and inadequate finance schemes are the barriers to the adoption of smart building practices in Abuja, Nigeria. Based on the research findings, it is recommended that AEC regulatory bodies and stakeholders in Nigerian construction industry should establish specialized and certification programmes, provide adequate electricity and high-speed internet service and foster collaborations between government agencies to enhance the adoption of Smart Building Practices in the study area.

Keywords: Construction industry, smart building concept, digitalization, urbanization, Abuja, Nigeria.

Introduction

The purpose of buildings is to fulfill the requirements and preferences of their inhabitants, with an increasing focus on enhancing comfort within the living environment. The United Nations Environment Programme (UNEP, 2018) has estimated that about 70% of the global population will be living in the cities by the year 2050, that is, one-third rural and two third urban, which is a reverse of the global rural-urban population distribution pattern in midtwentieth century resulting in expansion of the urban environment. This is due to the skyrocketing population growth, urban sprawl and globalization, the building industry is confronted with the challenge of providing adequate and holistic built infrastructures such as efficient energy management, good water supply, occupants' indoor comfort, and construction waste management (Indrawati, Yuliastri & Amani, 2017). Consequently, the construction industry is undergoing a transformative phase globally, driven by advancements in technology and the pressing need for sustainable development.

Technological penetration across developing countries has impacted the construction industry, with Architecture, Engineering and Construction (AEC) professionals' deploying various technologies into the building lifecycle's design, construction, management, and maintenance (Kochovski & Stankovski, 2018). The building industry has evolved by adopting sophisticated technologies such as the internet of things (IoT), smart devices (sensors), building information modelling and the smart building concept designed to enhance the efficiency, comfort, and sustainability of building operations (Froufe et al., 2020; Olawumi & Chan, 2020). Atamewan (2022), stated that one of the major solutions to the urbanization challenges especially that of climate change and excessive use of resources is the development of the concepts of smart buildings technologies.

The phrase "smart building" made its debut in 1981 when the United Technology Building Systems (UTBS) Corporation in the United States first introduced the concept (Baharetha et al., 2024). According to Indrawati, Yuliastri and Amani (2017) and Ogunde et al. (2018), the use of smart buildings concept has gained traction among construction professionals and academics all over the world to preserve the environment and advance the construction industry's building sector. A notable milestone occurred in 1983 with the construction of the City Place building in the United States, which was proudly marketed as the world's inaugural intelligent building that integrate automated systems (BMS) for the regulation of security and HVAC systems (Fabi et al., 2017; Pramanik et al., 2019; Baharetha et al., 2024). This growing embrace of 'building smartness' is a reaction to the negative environmental effects of the greenhouse emissions from conventional buildings that use high volumes of energy (Awosode, 2018). Several studies have been carried out to discuss the conceptualization of smart buildings (Ghaffarianhoseini et al., 2016; Baharetha et al., 2024); however, there is no consensual definition (Omar, 2018) which can directly impact in its design due to the absence of specific and commonly accepted criteria.

The smart building concept (SBC) has change traditional building construction and maintenance methods and offer users an interactive security, data networking, flexible, productive, economic, integrated, dynamic environment control, green energy, zero emissions, saves time and energy; promotes health and maintenance of the building life cycle, which complies with the ecosystem, economic and social life (Fabi et al., 2017; Gbadamosi et al., 2019; Pramanik et al., 2019; Sathesh & Hamdan, 2021; Hamida, Hassanain & Al-Hammad, 2022; Saad et al., 2022). Indrawati, Yuliastri and Amani (2017), defined the smart building concept as the collaboration of building automation systems, integration systems, and telecommunication systems for the smart building's efficiency, functionality, optimization, comfort, and economic stability. In the same vein Ejidike (2022), opined that smart building leverage Internet of Things (IoT) devices, automated control systems, and advanced analytics to optimize energy usage, improve security, and provide real-time monitoring and management of building systems. Similarly, the Intelligent Building Institute of the United States defined a smart building as a structure that optimizes its four essential elements: structures, systems, services, and management, as well as the interrelationships between them, to deliver a productive and cost-effective environment (Omar, 2018).

The construction industry in developed and developing countries has greatly adopted the smart building principles. Honeywell and IHS (2015), reported that developed counties like the UK and the United States is already in use for the planning and construction of buildings in cities such as San Francisco, which use the concept for the generation of 227 000 kilowatthours per year, through the incorporation of an integrated hybrid solar array and wind turbine installation. In Indonesia, using a smart building has positively impacted the economy and people's lives, satisfying their wants and needs, and the use of the smart building has been able to save energy and reduce energy power from 765,228.16 kWh to 499,067.01 kWh equal to a 34.78% reduction (Indrawati, Yuliastri & Amani, 2017). Technologies applied to smart buildings require specific knowledge on the part of project, construction, operation, and maintenance management teams (Ghaffarianhoseini et al., 2016), dealing with large volumes of data generated by building systems (Pašek & Sojková, 2018) and the need to control energy management.

Owusu-Manu et al (2021), stated that adopting smart building concept is subject to many critical factors, and these factors should be identified and understood. Similarly, Kashada, Li, and Kashadah (2016), opined that adopting the smart building concept includes five stages: the awareness, conviction, decision-making, implementation and confirmation stage. Ogunde et al. (2018), stressed that awareness of the smart building concept is vital for the adoption and implementation in the building sector of the construction industry. However, research in developing countries indicates that the adoption of smart building concepts, attributed to a low level of awareness and cognizance of smart building concept amongst construction professionals, is still low (Chan et al., 2017). The Nigerian building industry represents a multifaceted sector that encompasses construction, architecture, engineering, and allied trades, playing a pivotal role in the nation's economic growth and urban development. In Nigeria, the Federal Capital Territory (FCT), Abuja, represents a microcosm of the country's broader economic and developmental ambitions (Obafem & Raji, 2022). The city's construction industry is a significant contributor to its growth, driven by both public and private investments in residential, commercial, and infrastructural projects. Ejidike, Mewomo and Anugwo (2022), stated that majority of Nigerian construction professionals are generally aware of the smart building concept. Unfortunately, Ogunde et al. (2018), Ejidike (2022), Ejidike and Mewomo (2023), discovered that the high cost of smart building materials, inadequate power supply, resistance to change from the use of traditional technology, poor maintenance culture, poor knowledge of smart building technology, inadequate well-trained labour in the practice of smart building construction, and inadequate finance schemes are the significant barriers to the adoption of smart building concept in Nigeria. Similarly, Shen, Zhang and Long (2017) and Li et al (2020), identified lack of specialized and qualified suppliers and manufacturers for smart building systems. Ahn et al. (2013) identified lack of building code and regulation, promotion by the government, long payback period, financing schemes and uncertainties involved in adopting new technologies. Luthra et al. (2015) identified the lack of ability to meet electric power demand, unavailability of solar radiation data, and lack of political commitment as barriers in the construction industry. Chan et al. (2018), Zhao et al (2021), Hamida, Hassanain and Al-Hammad (2022), identified a lack of knowledge and expertise in smart building systems hinder the successful implementation and operation of smart buildings. Chan et al. (2017), identified professionals' resistance to change.

Furthermore, Alanne and Sierla (2022), Zhao et al (2021), maintained that lack of historical databases of existing smart buildings' performance, lack of a clear taxonomy for smart buildings, or the organization of their various components and subsystems (Alfalouji et al., 2023), the absence of identified basic dimensions of smart buildings contributes to the difficulty in defining and assessing their performance (Ejidike & Mewomo, 2023), lack of clear and agreed-upon criteria for evaluating the environmental performance of smart buildings (ElMotasem, Khodeir & Eid, 2021; Bibri, 2021; Ghansah et al., 2021), lack of descriptive guidelines for the design of different systems in smart buildings (Alsolami, 2022), lack of measures to maintain the privacy and data security of users (Pramanik et al., 2019), lack of logistical support/logistical for procuring smart systems (Himeur et al., 2023), the complexity of the design process leading to increased costs and delays in the construction process (Ghaffarianhoseini et al., 2016), lack of understanding of the basis of design responsiveness of occupational health and safety precautionary measures from a technological point of view (Alanne & Sierla, 2022), high costs of devices and installations, purchasing and configuring the equipment required for smart buildings (Hamida, Hassanain & Al-Hammad, 2022, AlMuharraqi et al., 2022), the requirement of high cash flow and financing for smart building projects are the potential challenges facing the adoption of SBP by AEC.

Researchers Holt (2013), Hamida, Hassanain and Al-Hammad (2022), Alanne and Sierla, (2022), AlMuharraqi et al (2022), Alfalouji et al (2023), also noted that lack of skilled and specialized maintenance and operation technicians. El-Motasem, Khodeir and Eid (2021), concluded that the general challenges were re-categorized into six: lack of research work, absence of a comprehensive definition, absence of characteristics, vague objectives lack of framework. The integration of smart building technologies offers a potential solution to these issues, promising improvements in energy efficiency, reduced operational costs, enhanced occupant comfort, and better environmental performance. According to Atamewan (2022), Nigerian architects have high level of awareness on smart building initiatives, but their involvement level in design and construction is low. Eseosa and Temitope (2019a), stressed that there is a need to integrate the smart building system into the design method, construction operation, and management of building to reduce cost and energy usage in the building sector of the construction industry. Given that this research is a core responsibility of professionals in Nigerian construction industry, this study provides an empirical evaluation of how widely smart building practices have been adopted in Federal Capital Territory (FCT), Abuja, Nigeria, its challenges and strategies that can guide Architecture, Engineering and Construction (AEC) professionals' in promoting and adopting smart building practices (SBP) in a rapidly developing urban center with a growing demand for modern infrastructure.

Statement of the Problem

The construction industry in Abuja, Nigeria, is at a critical juncture, grappling with rapid urbanization, escalating demands for energy efficiency, and the urgent need for sustainable development (Eseosa & Temitope 2019). As Nigeria's capital city, Abuja faces the dual challenge of expanding its infrastructure to meet the needs of a growing population while also adhering to global sustainability standards. The adoption of smart building technologies presents a promising solution to these challenges, offering potential improvements in operational efficiency, energy management, and overall building performance. However, the extent to which these technologies have been adopted by professionals in the construction industry in Federal Capital Territory (FCT), Abuja, remains largely uncharted despite the global trend towards smart buildings. The lack of comprehensive studies on this subject creates a knowledge gap that this study aims to fill. Therefore, the study seeks to evaluate Architecture, Engineering and Construction (AEC) professionals' adoption of Smart Building practices (SBP) in Federal Capital Territory (FCT), Abuja, Nigeria, identify the barriers, and strategies that can enhance the adoption of SBP among AEC professionals in construction industry in Abuja, Nigeria.

Purpose of the Study

The main purpose of this study was to evaluate Architecture, Engineering and Construction (AEC) professionals' adoption of smart building practices (SBP) in FCT, Abuja, Nigeria. Specifically, the study examined:

1. The extent of SBP adoption among AEC professionals in construction industry in Abuja, Nigeria.
2. The barriers to the adoption of SBP among AEC professionals in construction industry in Abuja, Nigeria.
3. The strategies that can enhance the adoption of SBP among AEC professionals in construction industry in Abuja, Nigeria.

Research Questions

The following research questions guided the study;

1. To what extent are SBP adopted among AEC professionals in construction industry in Abuja, Nigeria?

2. What are the barriers to the adoption of SBP among AEC professionals in construction industry in Abuja, Nigeria?
3. What are the strategies that can enhance the adoption of SBP among AEC professionals in construction industry in Abuja, Nigeria?

Literature Review

This study reviews the general literature on critical factors for the successful adoption of smart building practices (SCP) in the Nigerian Construction industry. In study conducted by Ejidike (2022), assessed construction professionals' awareness of smart building concepts (SBCs) in the Nigerian construction industry and identify the parameters by which SBCs can be measured. A quantitative survey was carried out using a questionnaire to gather relevant data in the study area. This paper was conducted on 363 registered construction professionals in the Nigerian construction industry. The data collected were analyzed using the Kruskal Wallis H test and weighted mean, factor analysis, and binary regression analysis, and mean item score and agreement analysis technique. This paper indicated that the majority of Nigerian construction professionals are generally aware of the smart building concept. Furthermore, the Kruskal Wallis H test shows no significant difference between the awareness level of the various construction professionals. This paper further revealed energy management systems, IT network connectivity, safety and security management systems and building automation systems as the most significant parameters in which SBCs can be measured. This paper identified significant parameters influencing SBCs awareness in the Nigerian construction industry. These parameters can be integrated into the building during the design stage and can be incorporated into the policymaking process of construction firms to promote the awareness of SBCs and encourage practices related to construction sustainability.

Similarly, Atamewan (2022) examined the role of architects and ICT in development of smart buildings in Nigeria. Methodology of study is basically review of literatures, interviews and use of questionnaire survey. Questionnaires were employed to extract information from architects drawn from six States of the Niger Delta region of Nigeria, on their knowledge and involvement in smart building development. The retrieved data was analyzed using Cronbach's Alpha with Likert scores 1-3 and the results presented in tables and charts. The paper showed that although Nigerian architects have high level of awareness on smart building initiatives, but their involvement level in design and construction is low. The paper recommended among others that architects should become smart building compliant and creation of smart economy through provision of smart infrastructure in the country by the government.

In the same vein, Hojjati and Khodakarami (2016) assessed the acceptance of smart buildings in Iran using the technology acceptance model (TAM). The study adopted descriptive survey. data were analyzed using correlational and casual study. Measurement tool was designed based on the standardized questionnaire presented by Davis. The reliability coefficient was 0.88. Statistical population was unlimited and included citizens of Iran in 1395. The sample consisted of 388 individuals. Given the infinity of society and Cochran formula, 384 individual was sufficient for this research. The study adopted a random sampling that was done in the period of 30 days. The intensity of relationship between variables in technology acceptance model and impact of each variable in explaining the criterion factor was analyzed. The results revealed that all relationships in the model were significant. Among the variables of the model, perceived usefulness, the attitude toward using, and features of smart buildings had the most intense relationship in accepting the technology. Using regression equations, each of the dependent variables in the model, was predictable by the independent variables.

Research Methodology

This section outlined the research framework, including the study's design, geographical scope, population, instrument validation, data collection, analysis methods, and decision criteria for evaluation of professionals' adoption of smart building practices in Nigerian construction industry. The study employed descriptive survey research design. According to Nworgu (2015), Johnny, Effiong and Sheik (2020), survey research design aims to systematically collect and describe data concerning the characteristics, features, or facts about a given population. The study was conducted in Abuja, the Federal Capital Territory and the administrative headquarters of Nigeria (Obafem & Raji, 2022). It has a landmass of about 8000km^2 (Badaru *et al*., 2014), with a current projected population of about 4,026,000 (Population Statistics, 2024). The FCT is divided into six area councils namely, Abaji, Abuja Municipal, Bwari, Gwagwalada, Kuje, and Kwali (Obafem & Raji, 2022).

The population of 628 Construction professionals consisted of 98 Architects, 117 Civil Engineers and 103 Electrical Engineers duly registered with the Architects Registration Council of Nigeria (ARCON) and Nigerian Society of Engineers (NSE). According to Bornstein, Jager, and Putnick (2013), the entirety of all elements under observation, which constitutes all things in any field of investigation, is the study population. Purposive sampling technique was used to select 154 Construction professionals consisted of 49 Architects, 54 Civil Engineers and 51 Electrical Engineers. A sample refers to a section or subset of the study population chosen for investigation through a sampling process (Taherdoost, 2021). In the same vein, Nardi (2018), stated that sampling technique is essential for estimating the required data volume and comprehending the data gathering process within a population to fulfill the study objectives. Yamane formula was used for calculating the sample size. According to Islam (2018), the Yamane formula provides a simplified formula to calculate sample sizes. The researchers developed a 30-item structured questionnaire titled: Evaluation of Architecture, Engineering and Construction (AEC) professionals' adoption of Smart Building

Practices in Abuja, Nigeria (EAECPASBPAN) Questionnaire. Questionnaire according to Nardi (2018), is the most common instrument or technique used to acquire descriptive data from a sample group in survey research because the respondents have the advantage of supplying data and information from the source. The instrument was divided into sections. Section A, B, C and D comprised of staff demographic data, level of adoption, challenges and strategies that can enhance the adoption of SBP among AEC professionals in construction industry in Abuja, Nigeria. The instrument was designed with a 5-point rating scale of Very High Extent (VHE=4.50-5.00), High Extent (HE=3.50-4.49), Moderate Extent (ME=2.503.49), Low Extent (LA=1.50-2.49), Very Low Extent (VLE=1.00-1.49) for research question 1 and Strongly Agreed (SA=4.50-5.00), Moderately Agreed (MA=3.50-4.49), Lowly Agreed (LA=2.50-3.49), Undecided (U=1.50-2.49), Strongly Disagreed (SD=1.00-1.49) was used to answer research questions 2 and 3.

In order to establish the validity of the instrument, copies of the instrument were given to one expert in the Department of Architecture, Civil and Electrical Engineering respectively, University of Abuja, FCT, Nigeria. To ensure the reliability of the instrument, it was trial-tested on 10 Architects, 10 Civil Engineers and 10 Electrical Engineers who were not part of the study. Cronbach alpha statistics was used to determine the reliability coefficient of the instrument which yielded overall reliability index of .80 comprising of .81, .83 and 77 for Section B, C and D respectively indicating that the instrument was reliable. Cronbach's alpha test according to Taber (2017) and Chan et al. (2018) is the most commonly used method to assess the accuracy of scales with value between 0 and 1. Furthermore, Sharma (2016) stated that the Cronbach's alpha coefficient should be between 0.7 and above to demonstrate the scale's reliability.

The data for the study were gathered from both primary and secondary sources. The primary data were collected using questionnaire while the secondary data were gathered from text books, journals and online materials (Google Scholar, Research Gates, Scopus, among others). The administration of the instrument was done with the help of 3 assistance who were briefed before administration of the instrument to the respondents. A letter of information and consent were part of the information provided to the participants. Since the questionnaire was distributed face to face, the participants read the letter of information and consent form and confirmed their voluntary participation. From the retrieved questionnaires, the overall response rate was 151(98%) and 145(96%) with appropriate response rate comprising of 47 Architects, 50 Civil Engineers and 48 Electrical Engineers were suitable for analysis. Mean scores and standard deviation were used for analyzing the data collated using Statistical Package for the Social Sciences 26 (SPSS).

Analysis of Data and Results

Research Question 1: To what extent are SBP adopted among AEC professionals in construction industry in Abuja, Nigeria?

Table 1: *The adopted of SBP among AEC professionals in construction industry in Abuja, Nigeria.*

S/N	**SECTION B:** The Level of Adoption of SBCs	**AR (N=47)**		**CE (N=50)**		**EE (N=48)**	
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
1.	Indoor Environmental Quality (IEQ) filtration systems that integrate energy-efficient heating, ventilation, air conditioning systems and non-toxic materials.	2.17	0.89	2.32	0.68	2.43	1.02
2.	Permeable pavements materials for walkways and parking areas to enhance stormwater management and reduce flooding risks.	2.26	0.77	2.40	0.64	2.38	0.73
3.	Smart lighting systems that integrate motion sensors and automated controls that adjust brightness based on occupancy and natural light availability	2.13	1.04	2.35	0.92	2.41	0.79
4.	Smart elevators integrating predictive algorithms and sensors to optimize travel routes and reduce wait times.	2.38	0.96	2.26	0.87	2.47	0.81
5.	Solar panels, wind turbines, and other renewable energy integration to reduce reliance on the grid and carbon footprints	3.06	0.71	2.48	1.21	2.52	1.02
6.	Water conservation technologies for greywater recycling, and water-efficient fixtures to minimize water consumption and promote sustainability.	2.27	1.13	2.41	0.84	2.46	0.67
7.	Smart waste management systems that automatically sort and manage waste, promoting recycling and reducing landfill contributions.	2.09	0.82	2.39	0.68	2.39	0.75
8.	Intelligent security systems that integrate smart cameras, access control systems, and biometric security measures to enhance safety and surveillance capabilities.	3.11	1.07	2.57	0.91	2.49	0.73
9.	Smart windows and glazing that integrate electrochromic or thermochromic glass that can adjust tint based on external conditions	2.12	0.99	2.58	0.83	2.45	0.89
10.	Building information modeling (BIM) for 3D modeling, planning, and simulation of construction processes.	3.01	0.84	2.53	0.80	2.48	0.92
	Grand Mean and Standard Deviation	**2.46**	**0.92**	**2.43**	**0.84**	**2.45**	**0.83**

NOTE: Architects (AR), Civil Engineers (CE), Electrical Engineers (EE), VHE (4.50-5.00), HE (3.50-4.49), MA (2.50-3.49), LA (1.50-2.49), VLE (1.00-1.49)

The analyzed data in Table 1 revealed that Architects and Electrical Engineers moderately adopt solar panels, wind turbines, and other renewable energy to reduce reliance on the grid and carbon footprints in smart buildings. In the same vein, Architects and Civil Engineers moderately adopt in intelligent security systems that integrate smart cameras, access control systems, biometric security measures to enhance safety and surveillance capabilities as well as Building information modeling (BIM) for 3D modeling, planning, and simulation of construction processes. The findings showed grand mean and standard deviation of 2.46(0.92), 2.43(0.84) and 2.45(0.83) on the extent SBP are adopted among AEC professionals in construction industry in Abuja, Nigeria. The result implies that Architecture, Engineering and Construction (AEC) professionals lowly adopt Smart Building Practices in Abuja, Nigeria.

Original Article

Research Question 2: What are the barriers to the adoption of SBP among AEC professionals in construction industry in Abuja, Nigeria?

Table 2: *Barriers to the adoption of SBP among AEC professionals in construction industry in Abuja, Nigeria*

S/N	**SECTION C:** Barriers to the Adoption of SBCs	**AR (N=47)**		**CE (N=50)**		**EE (N=48)**	
1.	Inadequate specialized and qualified suppliers and manufacturers for smart building systems.	4.58	0.72	4.63	0.59	4.78	0.44
2.	The complexity of managing large volumes of data during the design process.	4.52	0.66	4.58	0.78	4.55	0.63
3.	The requirement of high cash flow and funds for devices and installations.	4.74	0.86	4.61	0.75	4.77	0.68
4.	Lack of knowledge and expertise of smart building systems.	4.68	0.78	4.73	0.54	4.66	0.71
5.	Lack of understanding of users' needs for smartness	4.59	0.74	4.67	0.88	4.85	0.52
6.	Inadequate historical databases of existing smart buildings' performance.	4.66	0.67	4.66	0.59	4.76	0.73
7.	Continuous change in operation and maintenance requirements, which affects controlling and monitoring capabilities for systems' effectiveness.	4.51	0.77	4.62	0.45	4.58	0.64
8.	Inadequate availability and accessibility of sustainable and intelligent materials and equipment.	4.75	0.84	4.54	0.93	4.63	0.69
9.	Smart building projects are subject to variations that result in an excessive increase of time allocated.	4.81	0.87	4.65	0.79	4.71	0.61
10.	Lack of consumers' (e.g., designers, owners, and users) awareness of the technical specifications of smartness.	4.65	0.68	4.86	0.71	4.59	0.75
	Grand Mean and Standard Deviation	**4.65**	**0.76**	**4.66**	**0.70**	**4.69**	**0.64**
	Among AEC professionals	$\bar{x}$	**SD**	$\bar{x}$	**SD**	$\bar{x}$	**SD**

NOTE: Architects (AR), Civil Engineers (CE), Electrical Engineers (EE), SA (4.50-5.00), MA (3.50-4.49), LA (2.50-3.49), U (1.50-2.49), SD (1.00-1.49)

The analyzed data in Table 2 revealed that Architects, Civil Engineers and Electrical Engineers strongly agreed that all the items are barriers hindering the adoption of SBP among AEC professionals in construction industry in Abuja, Nigeria. The findings showed grand mean and standard deviation of 4.65(0.76), 4.66(0.70) and 4.69(0.64) on the barriers hindering the adoption of SBP among AEC professionals in construction industry in Abuja, Nigeria. The result implies that all the items are challenges hindering the adoption of SBP among Architecture, Engineering and Construction (AEC) professionals in construction industry in Abuja, Nigeria.

Research Question 3: What are the strategies that can enhance the adoption of SBP among AEC professionals in construction industry in Abuja, Nigeria?

Table 3: *Strategies that can enhance the adoption of SBP among AEC professionals in construction industry in Abuja, Nigeria.*

S/N	**SECTION D:** Strategies that can Enhance Adoption of SBP Among AEC Professionals	**AR (N=47) (N=48)**		**CE (N=50)**		**EE**	
		$\bar{x}$	**SD SD**	$\bar{x}$	**SD**	$\bar{x}$	
1.	Establish centers, innovation hub or technology clusters focused on smart building technologies to spur entrepreneurship and investment.	4.92	0.64	4.61	0.73	4.79	0.58
2.	Develop clear guidelines on design, installation, and maintenance of smart building technologies to ensure quality and consistency.	4.78	0.66	4.84	1.04	4.85	0.46
3.	Conduct extensive awareness campaigns on the long-term benefits of smart buildings, such as energy savings, enhanced security, and improved occupant comfort	4.73	0.62	4.69	0.79	4.76	0.6
4.	Support the local production of smart building technologies to reduce costs and dependency on importation.	4.66	0.71	4.70	0.65	4.87	0.49
5.	Establish specialized and certification programmes to equip construction professionals with the skills required for smart building design and implementation	4.59	0.68	4.77	0.81	4.54	1.06
6.	Foster collaborations between government agencies, private sector companies, and international organizations to develop innovative financing solutions to promote smart building projects.	4.51	0.81	4.60	1.11	4.88	0.94
7.	Launch pilot projects and share case studies to demonstrate						

	feasibility and build confidence on successful implementations of smart buildings.	4.54	0.72	4.55	0.91	4.63	0.44
8.	Availability of high-speed internet to create a more conducive environment for the adoption of SBPs	4.67	0.63	4.75	1.07	4.72	0.56
9.	Stable electricity to create a more conducive environment for the adoption of SBPs	4.85	0.78	4.93	0.71	4.76	0.82
10.	Establish a feedback mechanism to gather input from construction professionals driving continuous and innovation in smart building practices.	4.58	0.89	4.59	0.81	4.62	0.74
	Grand Mean and Standard Deviation	**4.68**	**4.74 0.71**	**4.70**	**0.86**		**0.67**

NOTE: Architects (AR), Civil Engineers (CE), Electrical Engineers (EE), SA (4.50-5.00), MA (3.50-4.49), LA (2.50-3.49), U (1.50-2.49), SD (1.00-1.49)

The analyzed data in Table 2 revealed that Architects, Civil Engineers and Electrical Engineers strongly agreed that all the items are strategies that can enhance the adoption of SBP among AEC professionals in construction industry in Abuja, Nigeria. The findings showed grand mean and standard deviation of 4.68(0.71), 4.70(0.86) and 4.74(0.67) on the strategies that can enhance the adoption of SBP among AEC professionals in construction industry in Abuja, Nigeria. The result implies that all the items are strategies that can enhance the adoption of SBP among Architecture, Engineering and Construction (AEC)professionals in construction industry in Abuja, Nigeria.

Discussion of Findings

The analyzed data in Table 1 revealed that Architects and Electrical Engineers moderately adopt solar panels, wind turbines, and other renewable energy to reduce reliance on the grid and carbon footprints in smart buildings. In the same vein, Architects and Civil Engineers moderately adopt in intelligent security systems that integrate smart cameras, access control systems, biometric security measures to enhance safety and surveillance capabilities as well as Building information modeling (BIM) for 3D modeling, planning, and simulation of construction processes. The findings showed grand mean and standard deviation of 2.46(0.92), 2.43(0.84) and 2.45(0.83) on the extent SBP are adopted among AEC professionals in construction industry in Abuja, Nigeria. The result implies that Architecture, Engineering and Construction (AEC) professionals lowly adopt Smart Building Practices in Abuja, Nigeria. This finding was in line with the study by Chan et al. (2018), Zhao et al (2021), Atamewan (2022), Hamida, Hassanain and Al-Hammad (2022) who stated that professionals in construction industry have high level of awareness on smart building initiatives, but their involvement level in design and construction is low.

The analyzed data in Table 2 revealed that Architects, Civil Engineers and Electrical Engineers strongly agreed that all the items are barriers hindering the adoption of SBP among AEC professionals in construction industry in Abuja, Nigeria. The findings showed grand mean and standard deviation of 4.65(0.76), 4.66(0.70) and 4.69(0.64) on the barriers hindering the adoption of SBP among AEC professionals in construction industry in Abuja, Nigeria. The result implies that all the items are challenges hindering the adoption of SBP among Architecture, Engineering and Construction (AEC) professionals in construction industry in Abuja, Nigeria. This finding was in line with the study by Chigozie (2018), Ogunde et al. (2018), Ejidike (2022), Ejidike and Mewomo (2023)who discovered that the high cost of smart building materials, inadequate power supply, resistance to change from the use of traditional technology, poor maintenance culture, poor knowledge of smart building technology, inadequate well-trained labour in the practice of smart building construction, and inadequate finance schemes are the significant barriers to the adoption of smart building concept in the Nigerian construction industry.

The analyzed data in Table 3 revealed that Architects, Civil Engineers and Electrical Engineers strongly agreed that all the items are strategies that can enhance the adoption of SBP among AEC professionals in construction industry in Abuja, Nigeria. The findings showed grand mean and standard deviation of 4.68(0.71), 4.70(0.86) and 4.74(0.67) on the strategies that can enhance the adoption of SBP among AEC professionals in construction industry in Abuja, Nigeria. The result implies that all the items are strategies that can enhance the adoption of SBP among Architecture, Engineering and Construction (AEC) professionals in construction industry in Abuja, Nigeria. The finding of this study was in supported of Oyewole, Araloyin and Oyewole (2019), Ejidike (2022), Adebisi and Wahab (2023), and Baharetha et al (2024) who stated that development of a comprehensive regulatory framework and standards, promotion of public awareness and training and workshop programs such as conferences and seminars about the benefits of smart building technologies, collaboration between stakeholders, public sector, industry, and academia are the strategies that can enhance the adoption of smart buildings practices and technologies in construction industries.

Conclusion:

The adoption of smart building concepts in FCT, Abuja presents a significant opportunity to enhance efficiency, sustainability, and overall building performance in one of Nigeria's fastest-growing urban centers. The finding of the study indicated that AEC professionals lowly adopt Smart Building Practices in the study area. The study findings also showed that high cost of smart building materials, inadequate power supply, poor knowledge of smart building technology and inadequate finance schemes are the barriers to the adoption of smart building concept in Abuja, Nigeria. By fostering an environment that supports innovation and addresses the specific challenges identified in this study, Abuja can set a benchmark for other Nigerian cities aspiring to modernize their construction practices. Ultimately, the successful integration of smart building concepts holds the potential not only to transform Abuja's urban landscape but also to contribute significantly to Nigeria's sustainable development goals, ensuring a smarter, greener, and more resilient built environment for the future.

Recommendations

Based on this research finding, the researchers recommended that AEC regulatory bodies and stakeholders in Nigerian construction industry should:

1. Establish centers, innovation hub or technology clusters focused on smart building technologies to spur entrepreneurship and investment
2. Foster collaborations between government agencies, private sector companies, and international organizations to develop innovative financing solutions, such as green bonds and sustainability-linked loans to promote smart building projects.
3. Establish specialized and certification programmes to equip construction professionals with the skills required for smart building design and implementation.
4. Improve critical infrastructure, particularly reliable electricity and high-speed internet to create a more conducive environment for the adoption of SBPs.
5. Conduct extensive awareness campaigns on the long-term benefits of smart buildings, such as energy savings, enhanced security, and improved occupant comfort.
6. Support the local production of smart building technologies to reduce costs and dependency on importation.
7. Develop clear guidelines on design, installation, and maintenance of smart building technologies to ensure quality and consistency.
8. Launch pilot projects and share case studies to demonstrate feasibility and build confidence on successful implementations of smart buildings.

References

Adebisi, O.D. & Wahab, A.B. (2023). Factors Influencing Adoption of Building Management System in Commercial Buildings in Lagos State, Nigeria. *African Journal of Housing and Sustainable Development, 4*(1),49-59. http://ujh.unilag.edu.ng/index.php/ajhsd.

Ahn, Y.H., Pearce, A.R., Wang, Y., & Wang, G. (2013). Drivers and Barriers of Sustainable Design and Construction: The Perception of Green Building Experience. *International Journal of Sustainable Building Technology and Urban Development*, 4 (1),35-45.

Alanne, K., & Sierla, S. (2022). An overview of machine learning applications for smart buildings. *Sustainable Cities Society*, 76(10),34-45. doi:10.1016/j.scs.2021.103445

Alfalouji, Q., Schranz, T., Falay, B., Wilfling, S., Exenberger, J., & Mattausch, T. (2023). Cosimulation for buildings and smart energy systems: A taxonomic review. *Simulation*

Modelling Practices and Theory, 126, Article 102770. doi:10.1016/j.simpat.2023.102770

AlMuharraqi, M., Sweis, G., Sweis, R. & Sammour, F. (2022). Factors affecting the adoption of smart building projects in the Kingdom of Bahrain. *Journal of Building and Engineering*, 62, Article 105325. doi:10.1016/j.jobe.2022.105325.

Alsolami, B.M. (2022). Identifying and assessing critical success factors of value management implementation in Saudi Arabia building construction industry. *Ain Shams Engineering Journal*, 6, Article 101804. doi:10.1016/j.asej.2022.101804.

Atamewan, E.E. (2022). Smart building projects in Nigeria - the role of Architects. *Unicross Journal of Science and Technology*, 1(1),1-14. Retrieved on January 15, 2024 from www.unicrossjournals.com.

Awosode, O.R. (2018). Adoption of Automation in Facility Management of High-Rise Buildings in Lagos, Nigeria. *Unpublished M.Sc. thesis* in Estate Management, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria.

Badaru, Y.U., Adejoke, A.O., Abubakar, A.S., & Emigilati, M.A. (2014). Rainfall variations as the determinant of malaria in the Federal Capital Territory, Abuja, Nigeria. *Journal of Environment and Earth Science*, 4(20),149-159.

Baharetha, S., Soliman, A.M., Hassanain, M.A., Alshibani, A. & Ezz, M.S. (2024), Assessment of the challenges influencing the adoption of smart building technologies. *Frontiers in Built Environment*, 9(1),33-40. doi: 10.3389/fbuil.2023.1334005.

Bibri, S.E. (2021). Data-driven smart eco-cities and sustainable integrated districts: a bestevidence synthesis approach to an extensive literature review. *European Journal of Future Resources*, 9(16),1-43. doi:10.1186/s40309-021-00181-4

Original Article

Bornstein, M.H., Jager, J., & Putnick, D.L. (2013). Sampling in Developmental Science: Situations, Shortcomings, Solutions, and Standards. *Developmental Review* 33 (4), 357– 370

Chan, A.P.C., Darko, A., Ameyaw, E.E., & Owusu-Manu, D.G. (2017). Barriers Affecting the

Adoption of Green Building Technologies. *Journal of Management in Engineering* 33 (3), 1-38.

Chan, A.P.C., Darko, A., Olanipekun, A.O., & Ameyaw, E.E. (2018). Critical Barriers to Green Building Technologies Adoption in Developing Countries: The Case of Ghana. *Journal of Cleaner Production,* 172 (1),1067-1079. https://doi.org/10.1016/j.jclepro. 2017.10.235.

Chigozie, I. (2018). Builder’s View on The Incessant Building Failures and Collapse in Nigeria: A Call for An Effective National Building Code. *American Journal of Engineering Research,* 7 (10),173-180. Retrieved on December 12, 2023 from www.ajer.org

Ejidike, C.C. (2022). Assessment of construction professionals’ awareness of the smart building concepts in the Nigerian construction industry. *Thesis research* submitted to the Department of Construction Management and Quantity Surveying, Faculty of Engineering and the Built Environment at the Durban University of Technology, South Africa.

Ejidike, C.C., & Mewomo, M.C. (2023). Benefits of adopting smart building technologies in building construction of developing countries: review of literature. *Spinger Nature*

Applied Sciences, 5(2),5- 52. doi:10.1007/s42452-022-05262-y

El-Motasem, S., Khodeir, L.M., & Eid, A. (2021). Analysis of challenges facing smart buildings projects in Egypt. *Ain Shams Engineering Journal*, 12 (3), 3317–3329.

doi:10.1016/j.asej.2020.09.028

Eseosa, O. & Temitope, F.I. (2019). Review of Smart Based Building Management System. *World Journal of Innovative Research*, 7(2), 14-23.

Eseosa, O. & Temitope, I. (2019a). Design Optimization and Implementation of Smart Building Management System in Nigeria. *Journal of Instrumentation and Innovation Sciences,* 4 (3),1-16.

Fabi, V., Barthelmes, V.M., Schweiker, M., & Corgnati, S.P. (2017). Insights into the effects of occupant behaviour lifestyles and building automation on building energy use. *Energy Procedia* 140, 48-56. doi:10.1016/j.egypro.2017.11.122

Froufe, M.M., Chinelli, C.K., Guedes, A.L.A., Haddad, A.N., Hammad, A.W.A., & Soares, C.A.P. (2020). Smart Buildings: Systems and Drivers. *Buildings,* 10(9),1-20.

Gbadamosi, A.Q., Oyedele, L., Mahamadu, A.M., Kusimo, H., & Olawale, O. (2019). The Role of Internet of Things in Delivering Smart Construction. *CIB World Building Congress*, 17–21.

Original Article

Ghaffarianhoseini, A., Berardi, U., AlWaer, H., Chang, S., Halawa, E., & Ghaffarianhoseini, A. (2016). What is an intelligent building? Analysis of recent interpretations from an international perspective. *Architectural Science Review,* 59(5),338–357.

doi:10.1080/00038628.2015.1079164.

Ghansah, F.A., Owusu-Manu, D.G., Ayarkwa, J., Edwards, D.J., & Hosseini, M.R. (2021). Exploration of latent barriers inhibiting project management processes in adopting smart building technologies (SBTs) in the developing countries. *Construction Innovations,* 21 (4),685-707. doi:10.1108/CI-07-2020-0116.

Hamida, M.B., Hassanain, M.A., & Al-Hammad, A.M. (2022). Review and assessment of factors affecting adaptive reuse of commercial projects in Saudi Arabia. *International Journal Building Pathology Adaptation,* 40(1),1-19. doi:10.1108/IJBPA-04-2020-0033

Himeur, Y., Elnour, M., Fadli, F., Meskin, N., Petri, I., & Rezgui, Y. (2023). AI-big data analytics for building automation and management systems: A survey, actual challenges and future perspectives. *Artificial Intelligence Review,* 56(6),4929-5021. doi:10.1007/s10462-022-10286-2.

Hojjati, S.N. & Khodakarami, M. (2016). Evaluation of Factors Affecting the Adoption of Smart Buildings Using the Technology Acceptance Model. *International Journal Advanced Networking and Applications*, 7(6),2936-2943.

Holt, G.D. (2013). Asking questions, analyzing answers: Relative importance revisited. *Construction Innovations*, 14(1),2-16. doi:10.1108/CI-06-2012-0035

Honeywell & IHS (2015). Put Your Buildings to Work: A Smart Approach to Better Business Outcomes. Article 27. available from <http://www.krcresearch.com/wpcontent/uploads/2015/11/Honeywell_Smart_Building_Whitepaper-10-28-15.pdf>

Indrawati, A., Yuliastri, R., & Amani, H. (2017). Indicators to Measure a Smart Building: An Indonesian Perspective. *International Journal of Computer Theory and Engineering,* 9 (6),406–411.

Islam, M.R. (2018). Sample Size and Its Role in Central Limit Theorem (CLT). *International Journal of Physics and Mathematics,* 1(1),37-47. https://doi.org/10.31295/ijpm.v1n1.42.

Johnny, A.E., Effiong, A.I., & Sheik, I. (2020). Entrepreneurship development centre in Nigeria's tertiary institution and student's self-employment upon graduation. *American Journal of Social and Humanitarian Research,* 1(4),1-13.

Kashada, A., Li, H., & Kashadah, O. (2016). The Impact of User Awareness on Successful Adoption of Decision Support System DSS in Developing Countries: The Context of Libyan Higher Education Ministry. *American Scientific Research Journal for Engineering, Technology, and Sciences,* 16 (1),334–345.

Kochovski, P. & Stankovski, V. (2018). Supporting Smart Construction with Dependable Edge

Original Article

Computing Infrastructures and Applications. *Automation in Construction*, 8(5),182-192.

Retrieved on January 26, 2023 from <https://doi.org/10.1016/j.autcon.2017.10.008>

Li, Z., Zhang, J., Li, M., Huang, J., & Wang, X. (2020). A review of smart design based on interactive experience in building systems. *Sustainabilty,* 1(2),6760–6774. doi:10.3390/SU12176760.

Luthra, S., Kumar, S., Garg, D., & Haleem, A. (2015). Barriers to Renewable/Sustainable

Energy Technologies Adoption: Indian Perspective. *Renewable and Sustainable Energy Reviews* 41, 762–776

Mohammed, F., Ibrahim, O., & Ithnin, N. (2016). Factors Influencing Cloud Computing Adoption for E-Government Implementation in Developing Countries: Instrument Development. *Journal of Systems and Information Technology,* 18 (3), 297–327

Nardi, P.M. (2018). Doing Survey Research: A Guide to Quantitative Methods. Routledge Publishers.

Nworgu, B.G. (2015). *Educational research: Basic Issues and Methodology.* Ibadan: Wisdom Publishers.

Obafem, F.A. & Raji, A.B. (2022). Level of Education in Abuja, Nigeria. *International Journal of Social Science Studies*, 10(4),23-28. https://doi.org/10.11114/ijsss.v10i4.5559. Retrieved on October 6, 2023 from http://ijsss.redfame.com.

Ogunde, A., Emmanuel, I., Nduka, D., Ayedun, C.., & Ogunde, A. (2018). Assessment of Integration of Building Automation Systems in Residential Buildings in Developing Countries: Professionals` Perspectives. *International Journal of Civil Engineering and Technology,* 9 (6),577-585.

Olawumi, T.O. & Chan, D.W.M. (2020). Key Drivers for Smart and Sustainable Practices in the Built Environment. *Engineering, Construction and Architectural Management,* 27 (6),1257–1281.

Omar, O. (2018). Intelligent Building, Definitions, Factors and Evaluation Criteria of Selection. *Alexandria Engineering Journal,* 57 (4),2903–2910. https://doi.org/10.1016/j.aej.2018.07.004.

Owusu-Manu, D.G., Ghansah, F.A., Ayarkwa, J., Edwards, D.J., & Hosseini, R. (2021). Factors Influencing the Decision to Adopt Smart Building Technology (SBT) in Developing Countries. *African Journal of Science, Technology, Innovation and Development,* 0 (0),1–11. https://doi.org/10.1080/20421338.2021.1899761.

Oyewole, M.O., Araloyin, F.M., & Oyewole, P.T. (2019). Residents' Awareness and Aspiration for Smart Building Features: The Case of Okota, Lagos, Nigeria. *Nigerian Journal of Environmental Sciences and Technology,* 3 (1),30-40.

Pašek, J., & Sojková, V. (2018). Facility management of smart buildings. *International Review of Applied Sciences and Engineering,* 9(2),181-187.

Population Statistics (2024). United Nations World Population Prospects. Retrieved on

October 6, 2023 from <ahref=’https://www.macrotrends.net/global-metrics/cities/21976/abuja/population>Abuja,Nigeria.MetroAreaPopulation19502024.www.macrotrends.net

Pramanik, P.K. D., Mukherjee, B., Pal, S., Pal, T., & Singh, S.P. (2019). Green smart building:

requisites, architecture, challenges, and use cases. Green Build. *Management of Smart Automation*, 1–50. doi:10.4018/978-1-5225-9754-4.ch001

Saad, S., Alaloul, W.S., Ammad, S., Altaf, M., & Qureshi, A.H. (2022). Identification of critical success factors for the adoption of Industrialized Building System (IBS) in Malaysian construction industry. *Ain Shams Engineering Journal*, 13 (2),06-31. 101547.doi:10.1016/j.asej.2021.06.031

Sathesh, A., & Hamdan, Y.B. (2021). Smart home environment future challenges and issues: A survey. *Journal of Electronic Information,* 3 (1),1-14. doi:10.36548/jei.2021.1.001

Shen, L., Zhang, Z., & Long, Z. (2017). Significant Barriers to Green Procurement in Real Estate Development. *Resources, Conservation and Recycling,* 11(6), 160–168. http://dx.doi.org/10.1016/j.resconrec.2016.10.004.

Taherdoost, H. (2021). Data Collection Methods and Tools for Research; A Step-by-Step Guide to Choose Data Collection Technique for Academic and Business Research Projects. *International Journal of Academic Research in Management (IJARM),* 10 (1),10-38. https://hal.science/hal-03741847.

United Nations Environment Programme (UNEP, 2018). The Weight of Cities Resource Requirements of Future Urbanization. Paris: International Resource Panel Secretariat.

Zhao, S., Zhang, P., &Li, W. (2021). A study on evaluation of influencing factors for sustainable development of smart construction enterprises: case study from China. *Buildings* 11 (6), 221. doi:10.3390/buildings11.